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(54) Resilient clamping connection of electrical circuits

(57) A solderless connector effects connection between a multi-layer flexible circuit and a rigid electronic circuit. A first embodiment (Figure 1) is characterized by (a) wrapping separated layers of a two or more layer flexible circuit (12) about an elastomeric resilient member (30) such that the terminal ends of each layer are provided on one side of the resilient member and (b) clamping the combination onto a rigid circuit board (14). In a second embodiment (Figure 7A), a multi-layer flexible circuit (48) is provided with successive steps formed in each layer wherein the terminating portions of each circuit layer have a progressively longer length. This stepped multi-layer flexible circuit (48) is then clamped to a rigid circuit (118) by stepped rigid retainer plate (76), wherein a resilient elastomeric member (116) is positioned between the stepped flexible circuit (48) and the steps of the rigid retainer plate (76) such that uniform pressure is maintained on all layers during interconnection with another electronic circuit device (118). Resilient material may be associated with individual laminae of the stepped flexible circuit (Figure 7B, not shown).

FIG. 1

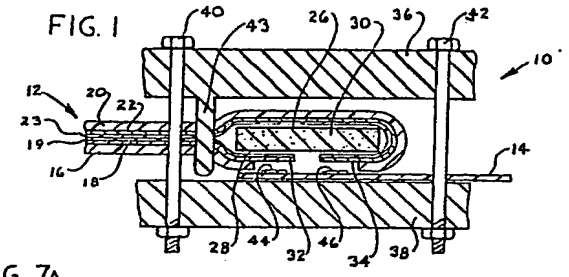
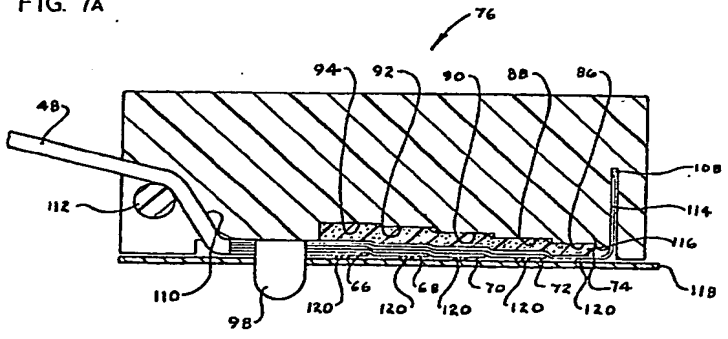


FIG. 7A



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.
This print embodies corrections made under Section 117(1) of the Patents Act 1977.

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FIG. 1

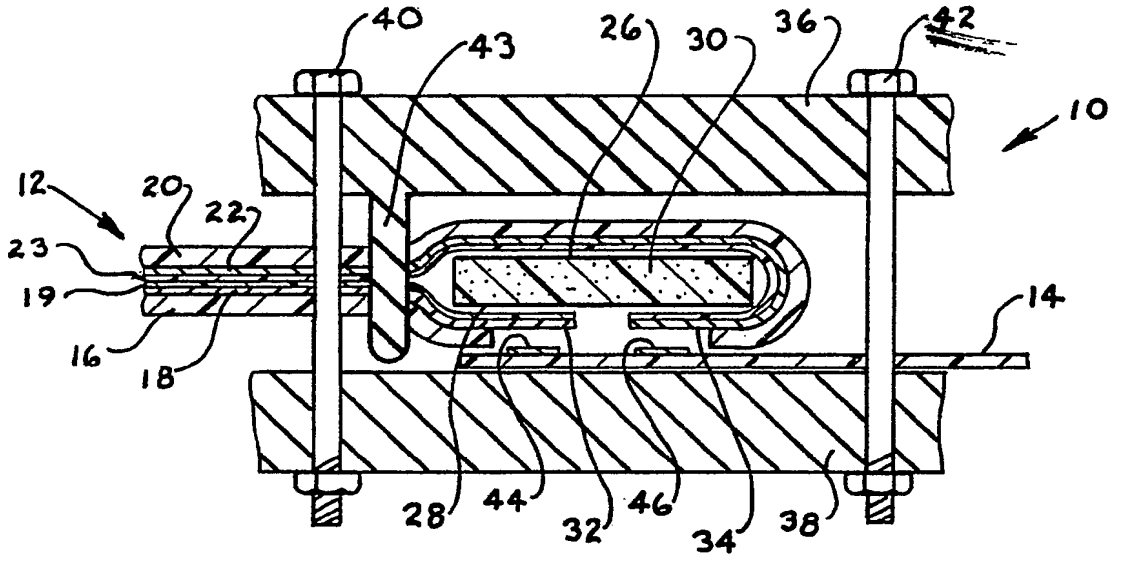
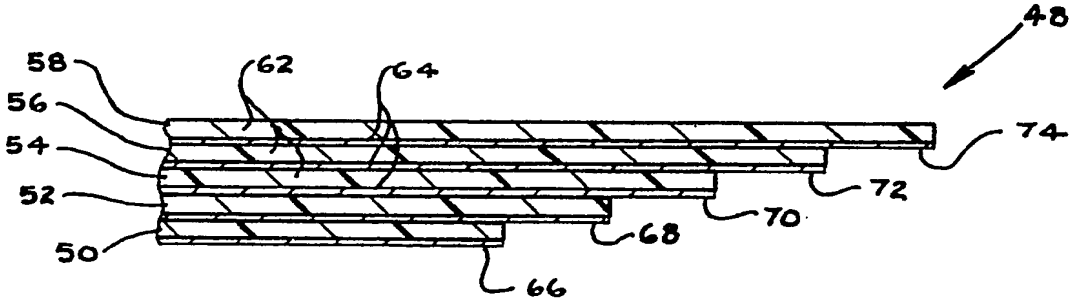


FIG. 2



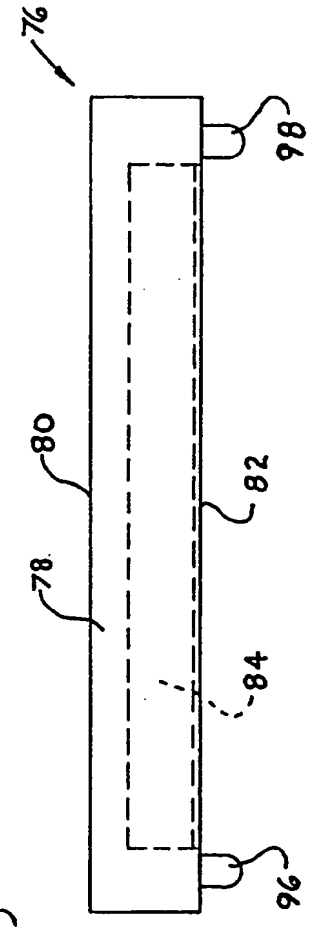


FIG. 3

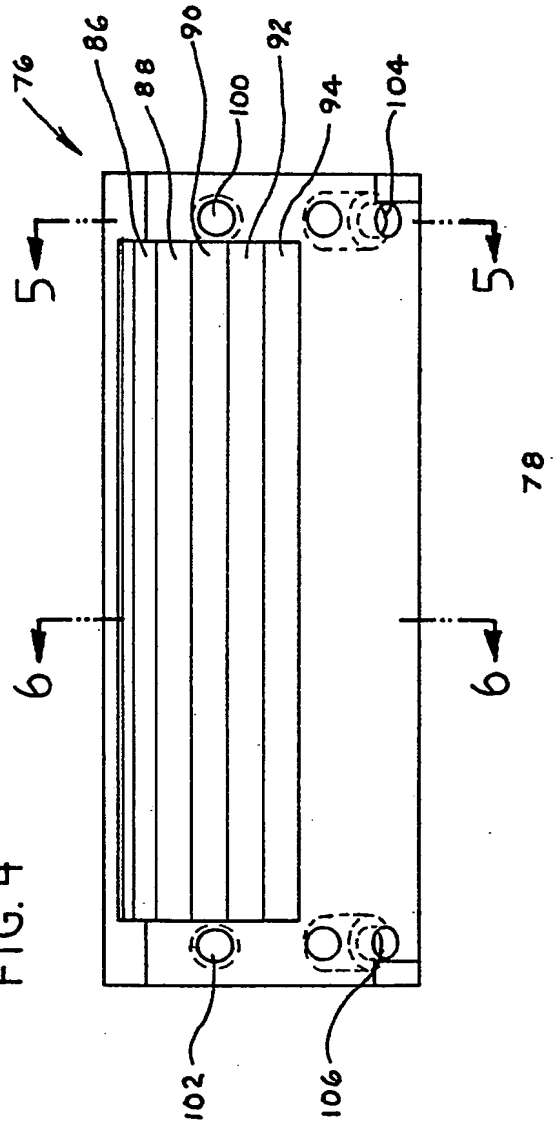


FIG. 4

FIG. 5

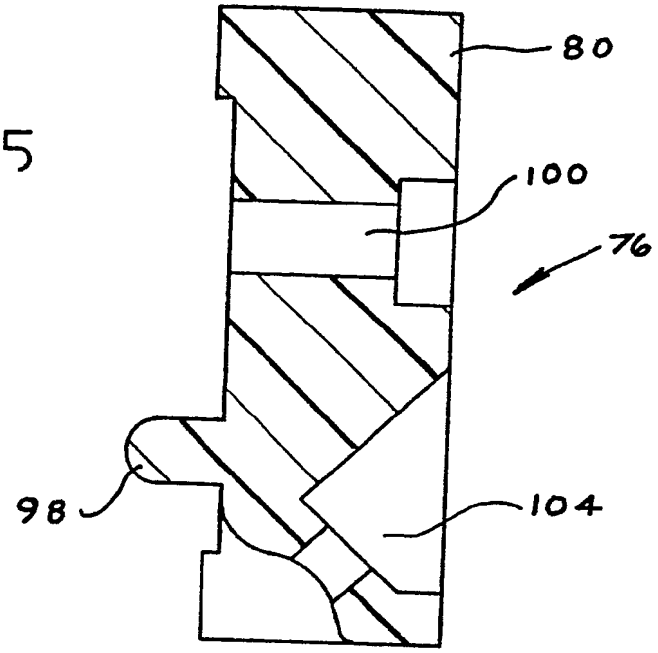
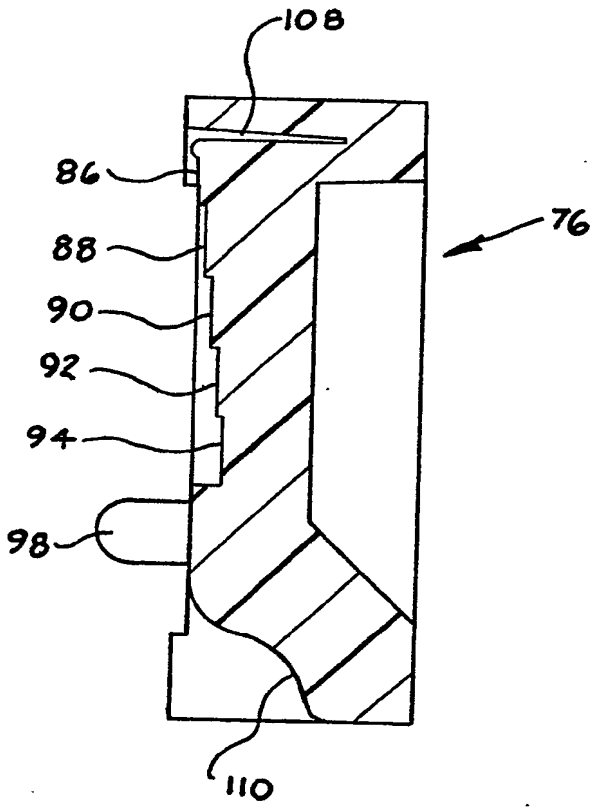


FIG. 6



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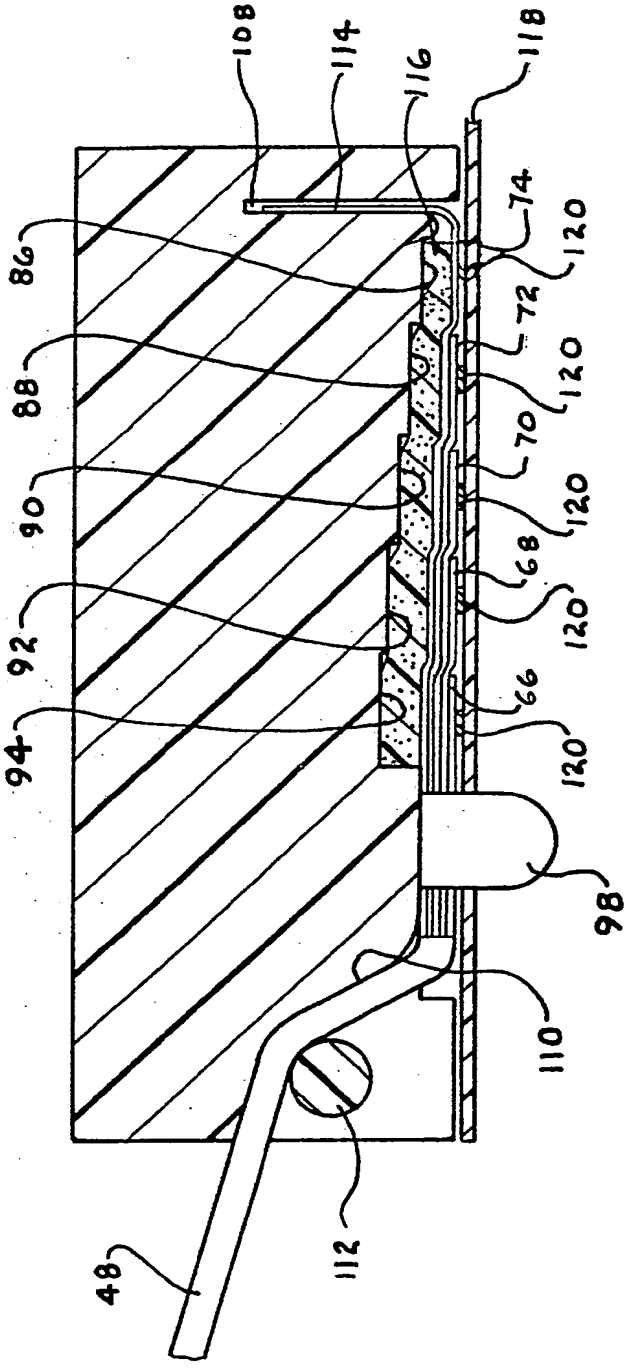

FIG. 7A

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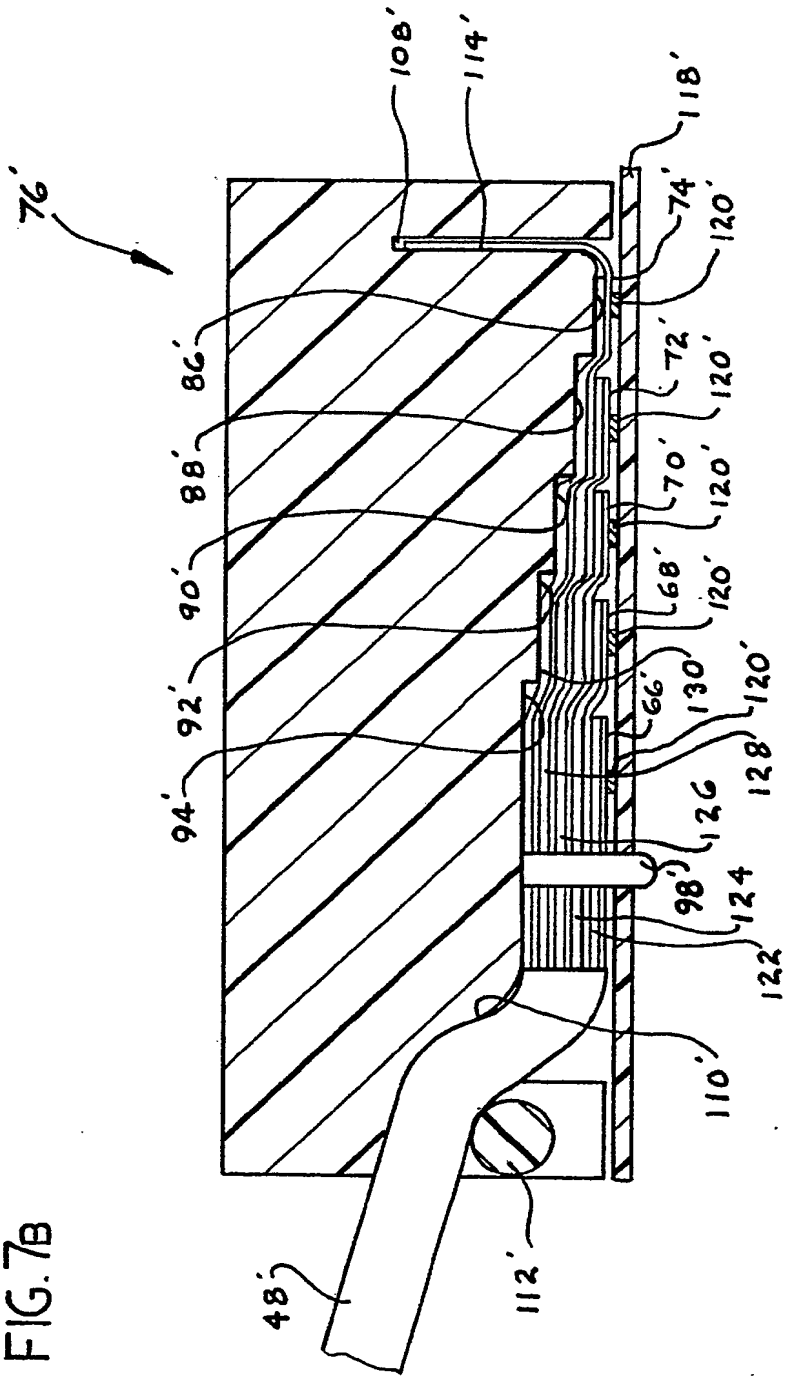


FIG. 7B

FIG. 8B

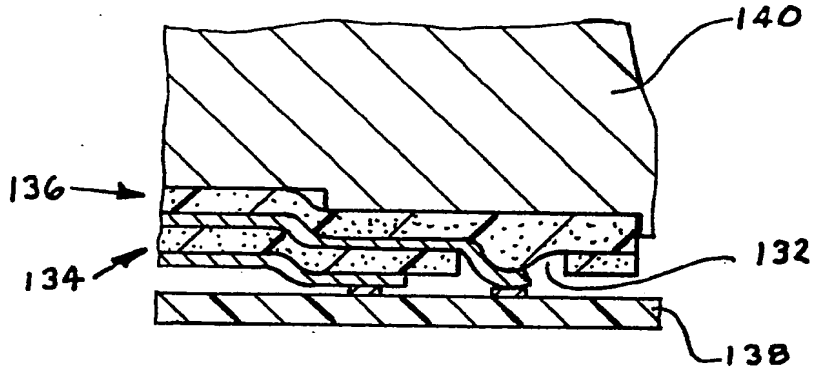
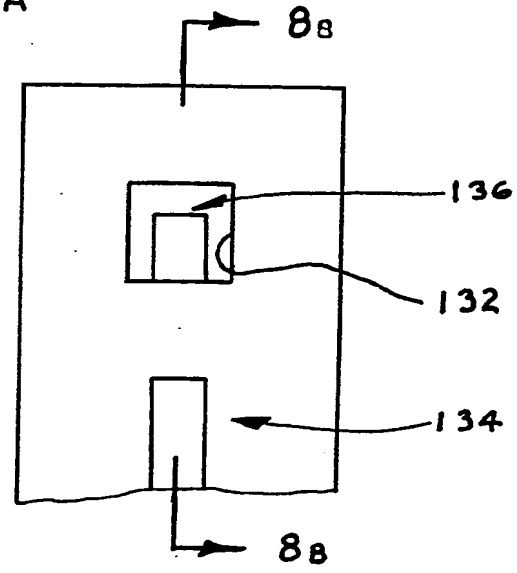


FIG. 8A



SPECIFICATION

Solderless connection technique and apparatus

This invention relates to a method and apparatus for interconnecting electrical circuit elements. More particularly, this invention relates to a new and improved solderless connector and method of using the same for establishing and maintaining electrical contact between multiple layer circuit devices. This invention is particularly well suited for connecting flexible circuits having two or more layers to another flexible circuit, a rigid circuit or an electronic component.

Conventional methods of interconnecting electrical or electronic circuit components consist of the use of separate connector structures and/or soldering terminals on the components to conductors which deliver current to or from the components. While generally suitable for its intended purposes, interconnecting electrical components via separate connector structures does suffer from certain drawbacks and deficiencies including high manufacturing and purchasing costs as well as increased labor time and costs during installation and connection. Similarly, soldering terminals is undesirable as the substrate which supports and exposed terminal must be able to withstand relatively high temperatures with no adverse effects. Also, soldering connections can be time consuming and therefore be labor intensive and expensive. Another problem with soldered connections is the relative difficulty in disconnecting a soldered terminal during repairs and manufacturing.

In some applications it has been found desirable to replace the use of separate connecting structures and/or soldering as a technique for use in establishing connections to flexible and other circuits. In these applications, the requisite electrical contact may be established by mechanically pressing the terminal portions of the circuit against terminal pads on the connector, device or another circuit. Such prior art pressure connections are customarily made with the aid of a solid resilient pressure applicator, such as an elastomeric member, which is placed in compression to bias at least one of the components to be electrically interconnected toward the other component to hold the terminal portions thereof in electrical contact. Such a solderless connection system is disclosed in US patent No 4,468,074.

US patent No 4,468,074 discloses an apparatus wherein contact portions of a first array of conductive elements are urged against mating contacts of a second array of conductive elements by a pressure applicator comprising a resilient open-celled plastic material thereby establishing and maintaining an electrical connection therebetween. The use of such an open-celled resilient material permits a plurality of closely spaced exposed electrical conductors on or extending from a pair of substrates to be aligned and thereafter reliably pressed together; with the electrical connections being established by a requisite contact pressure applied to the substrates. The solderless connector of Patent No 4,468,074 may be employed to interconnect flexible circuits; to connect flexible circuits to circuits on rigid substrates; to establish connections between the leads extending from integrated circuit in a circuit pattern on a flexible or rigid circuit board; and in other applications.

While suitable for its intended purposes, the solderless connector of Patent No 4,468,074 relates principally to the connection of single layer flexible circuits to other circuit devices. It will be appreciated that flexible circuitry comprising multiple layers of circuits are being increasingly utilized in the electronics industry. Unfortunately, prior art solderless connector devices are not well suited for effecting interconnections involving multi-layer flexible circuits. This is because each successive layer in a multi-layer flexible circuit imparts additional stiffness and rigidity to the flexible circuit as a whole. Consequently, the elastomeric force provided by the resilient pressure applicator becomes less effective leading to unreliable electrical contact.

In accordance with the present invention, a solderless connector is provided for establishing and maintaining electrical contact between multiple layer circuit devices, particularly interconnecting a multi-layer flexible circuit device to another flexible circuit, a rigid circuit board or any other electronic component.

In a first embodiment of the present invention, a technique is provided which utilizes a two or more layer flexible circuit wherein the two conductive surfaces face inwardly and are separated by aninsulating layer. Each circuit layer is then wrapped around oppositely disposed surfaces of a resilient elastomeric member such that the exposed terminal portions of the plural flexible circuits are positioned on the same plane of a single side of the elastomeric element.

In another embodiment of the present invention, a technique for effecting electrical connections between multi-layer flexible circuits having two or more layers, and other electronic circuit devices is provided. This embodiment utilizes a multi-layer flexible circuit wherein the terminal ends thereof each have different lengths; the bottom-most layer having the shortest length and the top-most layer having the longest length. Such a multi-layer flexible circuit is then used in conjunction with a rigid pressure plate which also has steps formed therein; however the steps formed in the rigid pressure plate have an opposite orientation to the steps formed in the flexible circuit layer. The solderless connector of this embodiment is assembled by providing a resilient elastomeric element between the rigid stepped pressure plate and the stepped multi-layer flexible circuit wherein the rigid pressure plate will force the terminal portions of the flexible circuit into electrical contact with another circuit device and wherein all of the stepped terminal portions of the flexible circuit will contact the other circuit device on the same plane and under a uniform pressure. Alternatively, the resilient elastomeric material may be provided between each layer in the multi-layer flexible circuit.

The above discussed and other advantages of the present invention will be apparent to and understood by those skilled in the art from the following detailed description and drawings.

Referring now to the drawings, wherein like el-

ements are numbered alike in the several figures;

Figure 1 is a cross-sectional elevation view of a two layer solderless connector device in accordance with the present invention;

Figure 2 is a cross-sectional elevation view of a five layer multi-layer flexible circuit used in accordance with the solderless connector of the present invention;

Figure 3 is a side elevation view of a rigid pressure plate suitable for interconnecting the multi-layer flexible circuit of Figure 2 with another circuit device in accordance with the solderless connector of the present invention;

Figure 4 is a bottom view of the rigid pressure plate of Figure 3;

Figure 5 is a cross-sectional elevation view along the line 5-5 of Figure 4;

Figure 6 is a cross-sectional elevation view along the line 6-6 of Figure 4;

Figure 7A is a cross-sectional elevation view of another embodiment of the multi-layer solderless connector in accordance with the present invention;

Figure 7b is a cross-sectional elevational view of still another embodiment of the solderless connector of the present invention;

Figure 8A is a bottom view of still another embodiment of the present invention; and

Figure 8B is a cross-sectional elevation view along the line B-B of Figure 8A.

The present invention relates to a solderless connector which is particularly well suited for connecting flexible circuits having two or more layers to other circuit devices. In Figure 1, a first embodiment of a solderless connector in accordance with the present invention is shown generally at 10. Solderless connector 10 is especially adapted for effecting electrical connection between a two or more layer flexible circuit shown generally at 12 and another circuit device; in this case, the circuit device being a rigid circuit board 14. In the particular illustrated example, solderless connector 10 utilizes a two layer flexible circuit having a first circuit layer and a second circuit layer. The first and second circuit layers respectively comprise a nonconductive base or substrate 16 and a cover film 19 sandwiching therebetween an electrically conductive circuit pattern means 18; and a nonconductive base or substrate 20 and a cover film 23 sandwiching therebetween an electrically conductive circuit pattern 22. The respective cover films 19 and 23 act as an insulating spacer between inwardly facing conductive circuit patterns 18 and 22 as shown in Figure 1. It will be appreciated that over most of the length of flexible circuit 12, the several circuit layers may be laminated together by a suitable adhesive material. However, the two circuit layers are separated at one end of the two layer flexible circuit as shown in Figure 1. Preferably one of the separated ends (i.e., substrate 20/pattern means 22) has a longer length than the other end. In this way, the two circuit layers may be wrapped around oppositely disposed sides 26 and 28 of a resilient elastomeric member 30 such that exposed terminal layers 32 and 34 of electrically conductive patterns 18 and 22, respectively, will be located on the same, i.e., lower, side 28 of elastomeric member 30. It will be appreciated that exposed terminal portions 32 and 34 are spacially separated to effect electrical insulation therebetween.

The two layer flexible circuit 12 used in conjunction with elastomeric member 30 as described above is well suited for use in conjunction with any conventional type of rigid clamp connector structure such as the one schematically shown in Figure 1. In Figure 1, the rigid clamp connector structure comprises upper and lower rigid plates 36 and 38 having bolts 40 and 42 or other suitable means for forcing plates 36 and 38 together. Preferably, alignment pins such as shown at 43 are provided to insure proper alignment between the flexible circuits and the rigid circuit board. In this way, the exposed terminal portions 32 and 34 of two layer flexible circuit 12 may effect electrical and mechanical contact with the respective terminal portions 44 and 46 on rigid circuit board 14. Significantly, the two layer flexible circuit 12/elastomeric pad 30 constructions of the present invention provides exposed terminal patterns on the same plane. This novel structure provides uniform pressure which permits a reliable electrical contact to be made when the respective terminal portions are mechanically pressed against each other via the clamping of pressure applicator.

While the solderless connector 10 of Figure 1 has been shown in conjunction with a two layer circuit solderless connector 10 may also effect electrical connections when the multi-layer flexible circuit has more than two circuit layers such as the five layer flexible circuit generally identified at 48 in Figure 2.

In accordance with a second embodiment of the present invention, five layer multi-layer flexible circuit 48 is comprised of successive circuit layers 50, 52, 54, 56 and 58, each individual circuit layer including a nonconductive substrate 62 having conductive circuit pattern 64 thereon, all of which are laminated together as shown in Figure 2. In accordance with the present invention, at one end of the multi-layer flexible circuit 48, the individual circuit layers 50-58 form a progressive step pattern. The steps are formed by providing progressively longer lengths to each individual circuit layer 50-58. Thus, circuit layer 50 has a shorter length relative to circuit layer 52 which in turn has a shorter length relative to circuit layer 54 until, eventually, the top most circuit layer 58 is reached. Accordingly, each successive circuit layer 50-58 includes an exposed terminal portion 66, 68, 70, 72 and 74. Preferably, the individual circuit layers 50-58 are not adhesively laminated together in the overlapping stepped or terminal portion 66-74 so as to maintain flexibility in those areas. Alternatively, a flexible adhesive such as R/Flex 20,000 manufactured by the Rogers Corporation may be used to laminate the overlapping terminal portions.

Referring now to Figures 3-6, the stepped multi-layer flexible circuit 48 of Figure 2 is used in conjunction with a rigid pressure plate or housing generally identified at 76. Rigid pressure plate 76 is specifically adapted to be used in conjunction with a multi-layer flexible circuit device such as flexible circuit 48 shown in Figure 2. Rigid plate 76 includes a housing 78, the housing having a top surface 80 and an bottom surface 82. Bottom surface 82 includes an op-

ening or cavity 84 which provides access from the bottom 82 of housing 78 to the interior thereof. The upper surface of cavity 84 includes a series of steps 86, 88, 90, 92 and 94 formed therein such that the depth of cavity 84 varies from smaller (at step 86) to larger (at step 94). Rigid pressure plate 76 also includes a pair of alignment pins 96 and 98; a pair of openings 100 and 102 for receiving a bolt or other securing device; and a pair of angled apertures 104 and 106. Housing 78 further includes a flexible circuit layer retaining slot 108 (see Figure 6) and a flexible circuit receiving ramp 110 and associated retaining clamp 112 (see also Figure 7A). Retaining clamp 112 is preferably a U-shaped clamp having a base section with two extensions on each end of the base. The extension are respectively received in each angled aperture 104 and 106 and can be held therein by a nut (not shown). The base section of the U-shape clamp urges the flexible circuit 48 against rigid plate 76 as shown in Figure 7A.

Turning now to Figure 7A, an assembled view of the solderless connector in accordance with the present invention is shown. In Figure 7A, a five layer flexible circuit such as the flexible circuit 48 in Figure 2 has been mounted on the rigid connector plate 76 via insertion thereof between the flexible circuit guide ramp 110 and associated clamp 112 such that the stepped portions or terminal portions 66-74 of multi-layer circuit 48 are aligned with and disposed under steps 94-86, respectively. It will be appreciated that the end flap 114 of upper circuit layer 60 is loosely engaged within retainer slot 108. In accordance with one embodiment of the present invention, an elastomeric resilient pressure member 116 is provided between the stepped portion of cavity 84 and the terminating portions of multi-layer flexible circuit 48. Alignment pins 96 and 98 are adapted to engage the flexible circuit 48 and another circuit device, such as rigid circuit board 118 so that the conductive circuit pattern 120 of rigid circuit board 118 will be properly aligned with selected terminal portion 66-74 of multi-layer flexible circuit 48. Thereafter, bolts (not shown) or other securing means are provided through bolt holes 100 and 102 and corresponding holes in rigid circuit board 118 to effect mechanical attachment of housing 80 to rigid circuit board 118.

As the solderless connector 76 is forced into mechanical engagement with rigid circuit board 118, resilient pressure member 116 will be placed in compression to bias the respective terminal portions of flexible circuit 48 with the respective terminal portions on circuit pattern 120. It will be appreciated that the corresponding stepped configuration of cavity 84 and multi-layer circuit 48 will permit each terminal portion 66-74 of the flex circuit to be on the same plane wherein uniform pressure will be maintained at each of the respective layers. Note that the top most layer 58, i.e., terminal portion 74, (having the longest length) of flexible circuit 48 is disposed beneath the step of housing 80 having the smallest depth (i.e., step 86); while the bottom most layer 50, i.e., terminal portion 66 (having the shortest length) is disposed beneath the step of housing 80 having the largest depth (i.e., step 94).

Turning now to Figure 7B, in an alternative embodiment of the pressure invention, a plurality of resilient pressure members 122, 124, 126, 128 and 130 are provided between each separate layer of multilayer flexible circuit 48'. This embodiment may be preferable to the embodiment of Figure 7A as each terminal section may be precisely tailored in conjunction with the relative amount of resilient material needed for the particular location (i.e., it may be desirable to provide more elastomeric resilient material under a step of larger depth than under a step having a smaller depth). Another advantage is that only one flexible circuit layer is being pressed by the resilient pressure pad thereby ensuring uniform pressure; unlike the Figure 7A embodiment wherein the pressure pad may be disposed over two or more circuit layers along the stair-step. It will be appreciated that the other structural components of Figure 7B are identical to the structural components already discussed with regard to Figure 7A with the addition of a prime.

Referring now to Figures 8A and 8B, alternatively windows or openings 132 may be punched from a lower circuit layer 134. Window 132 will thus provide access for a portion of an adjoining layer 136 to pass therethrough and contact a circuit board 138. These windows may be provided at location as desired. Preferably, the stair step structure of the rigid pressure plate 140 will be adjusted to provide adequate pressure in effecting electrical contact.

While the above discussion of Figures 2-7 have been with regard to a five layer multi-layer flexible circuit and a solderless connector having five steps therein it will be appreciated that the stepped solderless connector of the present invention suitable for interconnecting multi-layer circuits may utilize anywhere from two or more steps; the five step constructions shown in the figures being an example only.

In accordance with the present invention, the material which defines the elastomeric pad 30 of Figure 1, 116 of Figure 7A and 122, 124, 126, 128 and 130 of Figure 7B preferably consists of an open celled viscoelastic polymer and, in the preferred embodiment a polyurethane foam. Particularly good results have been obtained employing a urethane formulation comprising a mixed polyester/polyether system. One open cell material suitable for use in the practice of the present invention is FCD 2200 obtainable from Rogers Corporation. This material is characterized by a compressive load deflection at 25% compression in the range of $0{,}34.10^5$ to $3{,}4.10^5$ PA. A resilient material for use in the present invention is preferably characterized by a compression set of less than 5%. The compression set is tested in accordance with ASTM standard D-1564 wherein a 50mm square and 25 mm thick stack of sheets of material (about 1,5mm/sheet) are compressed 50% to 12,5mm thickness, the compressed material is subjected to 70°C for 22 hours, the compression is released and the thickness is measured. The compression set of the R/Flex 8770 material after 5 hours of steam autoclaving prior to performing test ASTM D-1564 is less than 10%.

The solderless connection of the present invention is particularly adapted to effect solderless inter-

connection between multi-layer flexible circuits and other electronic circuit devices while maintaining uniform pressure at the several terminal portions to be connected.

It will be appreciated that the solderless connector of the present invention is well suited for interconnecting a pair of flexible circuits, a flexible circuit to a rigid circuit and a flexible circuit to an integrated circuit or other electronic component.

CLAIMS

1. Solderless connector wherein mechanical means applies force against an elastomeric element to effect electrical contact between terminal portions of circuit devices, at least one of the circuit devices being a multi-layer flexible circuit having at least a first and second circuit layer, the improvement comprising said first layer of said flexible circuit including a first nonconductive substrate and a first cover film, said substrate and cover film sandwiching a first conductive pattern therebetween, said second layer of said flexible circuit including a second nonconductive substrate and a second cover film, said substrate and cover film sandwiching a second conductive pattern therebetween, said first and second conductive patterns facing inwardly toward each other and being separated by said first and second cover films, said first and second layers being bonded together to form a laminate, end portions of said first and second layers respectively extending outwardly of said flexible circuit and defining first and second extended circuit portions, said second extended circuit portion having a longer length than said first extended circuit portion, said first and second extended circuit portions having terminal portions at each end thereof, said elastomeric element having oppositely disposed first and second surfaces wherein said second extended portion is wrapped about all of said first surface and a portion of said second surface, and wherein said first extended portion is wrapped along a portion of said second surface so that both said first and second terminal portions are electrically isolated from each other and are positioned on said second surface of said elastomeric element, said terminal portions being adapted to electrically contact another circuit device.

2. A solderless connector as claimed in Claim 1, wherein said multi-layer flexible circuit includes a plurality of additional layers, said additional layers being wrapped along said elastomeric element and including extended circuit portions having terminal portions at the respective ends thereof, and wherein said terminal portions of said additional layer are positioned on said second surface of said elastomeric element, said additional terminal portions being electrically isolated from each other.

3. A solderless connector as claimed in Claims 1 or 2, including means for aligning said multi-layer circuit with another circuit device.

4. A solderless connector wherein mechanical means applies force against an elastomeric means to effect electrical contact between terminal portions of circuit devices, at least one of said circuit devices being a multi-layer flexible circuit having at least first and second layers, the connector comprising a rigid housing, said housing defining a pair of oppositely disposed first and second surfaces, said first surface including an opening therein, said opening including an upper surface spaced from said first surface and defining a depth of said opening, said opening being adapted to receive said elastomeric means and said multi-layer flexible circuit, at least one step being formed in said upper surface of said opening wherein said depth of said opening varies from smaller to larger, means for applying a force to said rigid housing to compress the elastomeric means and bias the respective terminal portions of the circuit devices into electrical contact.

5. A solderless connector as claimed in Claim 4, including a multi-layer flexible circuit, said multi-layer circuit comprising at least first and second layers, adjacent ends of said layers extending outwardly of each other at different lengths to define stepped terminal portions, said stepped terminal portions disposed beneath corresponding steps in said rigid housing, said terminal portion including exposed conductive circuit means, said conductive circuit means in facing relation to second conductive circuit means on another circuit device (118).

6. A solderless connector wherein mechanical means applies force against an elastomeric means to effect electrical contact between terminal portions of circuit devices, at least one of said circuit devices being a multi-layer flexible circuit having at least first and second layers, the connector comprising a rigid housing, said housing defining a pair of oppositely disposed first and second surfaces, said first surface including an opening therein, said opening including an upper surface spaced from said first surface and defining a depth of said opening, at least one step formed in said upper surface of said opening wherein said depth of said opening varies from smaller to larger, a multi-layer flexible circuit, said multi-layer circuit comprising at least first and second layers, adjacent ends of said layers extending outwardly of each other to define stepped terminal portions, said stepped terminal portions disposed beneath corresponding steps in said rigid housing, said terminal portions including exposed conductive circuit means, said conductive circuit means in facing relation to second conductive circuit means on another circuit device, and means for applying a force to said rigid housing to compress the elastomeric means and bias the respective terminal portions of the circuit devices into electrical contact.

7. A solderless connector as claimed in Claims 4 or 6, including elastomeric means positioned between said at least one rigid housing step and said multi-layer circuit steps.

8. A solderless connector as claimed in Claims 4 or 6, including elastomeric means positioned between each adjacent layer of said terminal portions.

9. A solderless connector as claimed in Claims 5 or 6, including means for urging said multi-layer flexible circuit against said rigid housing.

10. A solderless connector as claimed in Claim 9, wherein said urging means comprises a U-shaped clamp, and openings in said rigid housing to receive said U-shape clamp therein.

11. A solderless connector as claimed in Claims 5 or 6, including a slot in said rigid housing and wherein at least one of said layers of said multi-layer circuit is positioned in said slot.

12. A solderless connector as claimed in Claims 5 or 6, including a window provided in at least one of said layers wherein the terminal portion of an adjacent layer is disposed over said window, and wherein said terminal portion of said adjacent layer will pass through said window upon application of a force.

13. A solderless connector substantially as hereinbefore described and as illustrated in Figure 1 of the accompanying drawings.

14. A solderless connector substantially as hereinbefore described and as illustrated in Figures 3 to 6 of the accompanying drawings.

15. A solderless connector substantially as hereinbefore described and as illustrated in Figures 2 to 6 of the accompanying drawings.

16. A solderless connector substantially as hereinbefore described and as illustrated in Figures 3 to 6 and 7A of the accompanying drawings.

17. A solderless connector substantially as hereinbefore described and as illustrated in Figures 3 to 6 and 7B of the accompanying drawings.

18. A solderless connector substantially as hereinbefore described and as illustrated in Figures 8A and 8B of the accompanying drawings.

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